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Article

Distribution systems in apartment buildings

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Distribution systems in apartment buildings

In an apartment building, the two main principal heat and domestic hot water (DHW) distribution methods are the riser pipe system and the decentralized system with flat stations. In the first case, the DHW system heat losses may be bigger than the net heat for preparing the DHW. In the second case, the DHW pipes are only inside the apartments or flats and are mostly idle. Individual controls and metering will typically lead to considerable savings in heat consumption. The paper compares the decentralized system with flat stations to few versions of riser pipe systems involving investment, system heat losses, heat consumption, savings, and comfort level.

Introduction

Investigations in Denmark have shown, that individualisation of metering together with individual controls will lead to 10–30 % savings in heat consumption. Apartment buildings include a huge energy-saving potential, as they traditionally make up a big part of the DH consumers in most cities. Increasing focus on energy savings, together with more demands for comfort involve better controlling and metering possibilities for the individual consumer. For apartment buildings, this individualisation of the control equipment for district heating supply brings about a two-pipe system with thermostatic radiator valves and a separate district heating unit for each flat, where metering takes place, this we call a flat station. This design implies higher investment, but is justified by higher individual comfort combined with reduced energy demand.

The article includes a description of the geometry of an apartment building, a description of four different alternatives in block distribution systems, and a comparison of system heat losses as well as pipe recourses. The subjects of comfort level and individualisation of heat supply are involved together with saving potential.

Basic design alternatives

Basic Data of an Apartment Building

An apartment building used as reference is included in Fig. 1. It has the following dimensions:

- Staircase dimensions:
 $2,5 \times 4,5 \text{ m} = 11,3 \text{ m}^2$
- Flat – depth \times width \times height:
 $12 \times 12 \times 3,2 \text{ m}$ (without staircase)
- Flat size/area: $144 - 11 \text{ m}^2 = 133 \text{ m}^2$
- Number of stories: 4 + basement
- Number of flats per staircase: $4 \times 2 = 8$
- Number of flats in building block:
 $3 \times 8 = 24$
- Basement: $72 \times 12 \times 2,5 \text{ m}$
- Number of radiators per flat: 6
- Number of tapping sites per flat: 3
- Number of basement substations per building: 1

Other parameters are set to typical values.

Distribution system design alternatives

Only one DH substation or boiler in the basement serves the whole building. Here, hydraulic separation, temperature controls and heat metering take place, according to the local site conditions of pressures, temperatures, and requirements about heat metering. The block distribution system can be found in several basic versions, (Fig. 2) including:

- Riser Pipe system A, both domestic hot water (DHW) and room heating pipes rise through floors of flats
- Riser Pipe system B, DHW pipes rise through floors of flats, room heating pipes rise in staircase.
- Riser Pipe system C, both DHW and room heating pipes rise in stair cases. No flat floor penetrations of pipes.
- Flat station system F. Only “DH” and cold water pipes rise, and only in the staircase. A flat station supplies every apartment. All DHW and room heating pipes are placed inside the apartment without floor penetrations.

These four basic alternatives in distribution design can be found in several sub versions.

The Riser Pipe system A does not allow any separate heat metering for each flat or apartment, but this pipe system is cheap and simple to construct. The Riser Pipe system B allows only room heat metering as separate for every flat. The Riser Pipe system C allows separate metering for every flat of both room heat and domestic hot water, but the metering must take place in two separate heat meters. In the Riser Pipe system designs A, B and C, the consumers in the flats have no influence on the DHW temperature. Another withdrawal of the riser pipe systems A, B, C is that inexpedient temperatures in the DHW system may occur, involving increased risk for hygienic problems may (Fig. 3).

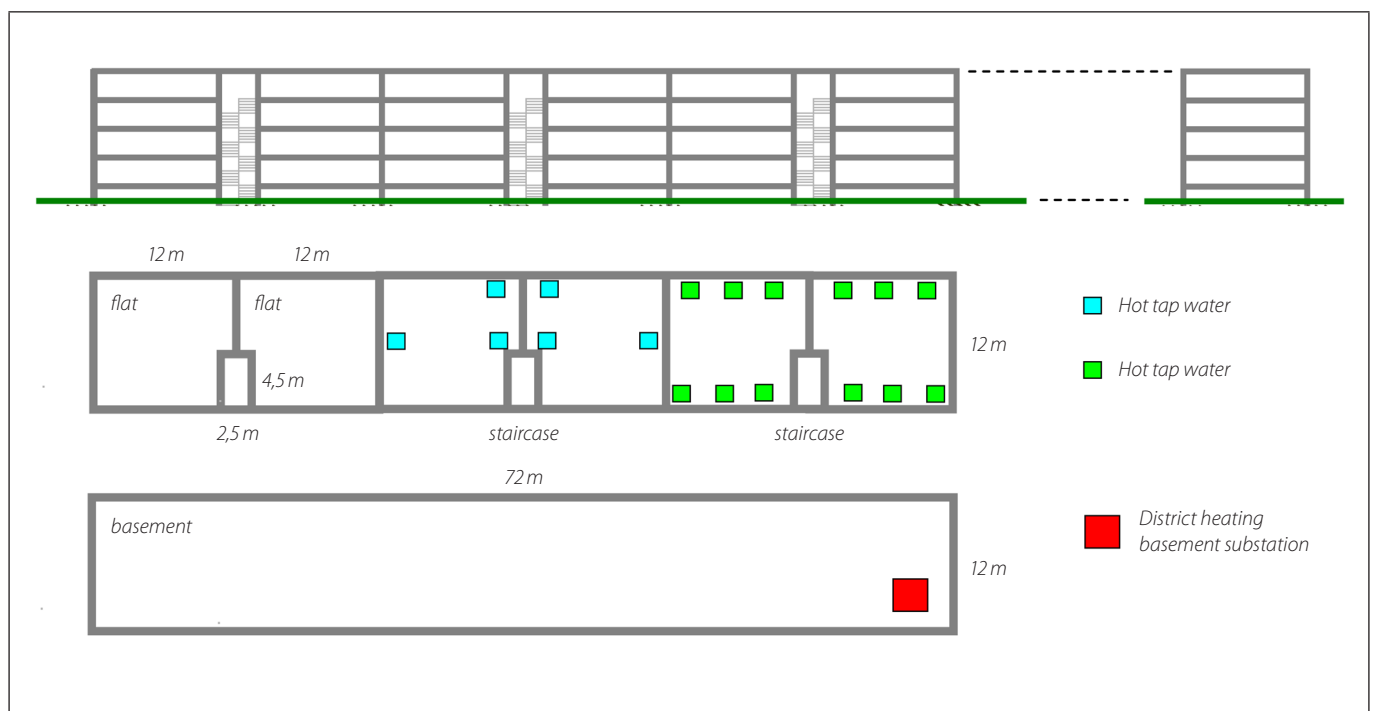


FIGURE 1: Sketch of an apartment building with basic geometry of a building, position of consumer installations and the basement DH substation

This makes it necessary to keep higher DHW temperature, than necessary if it was locally and instantaneously produced.

For the decentralized system with flat stations, the basement only includes DH pipes connected to one DH riser pipe pair in each staircase. All DHW and room heating pipes are placed inside the apartments, usually behind

nice-looking skirting boards. A basement substation or boiler with hydraulic separation, and/or temperature reduction, and/or a main heat meter is still an option, if required. The flat station can be placed inside the apartment or just outside in a locked box. The last is sometimes preferred, if the district heating enterprise service the station, and manually readout the heat meters.

The amount of piping in case of the four principal distribution alternatives is included in Fig. 4.

The red/orange colour indicates district heating pipes, the green colours indicates room heating pipes, and the blue colours indicates DHW pipes including circulation pipes. Cold water pipes are excluded in the analysis. In case of decentralized Flat Station



system F, the utility may be building main circulation pipes in case of hydraulic separation from district heating. Each of the 3 pipe type categories above have been divided up into two sub categories according to whether they are placed in basement without need for room heating, or in staircase and apartments, with need for room heating.

The Riser Pipe system A design involves the smallest amount of pipes. Therefore this system was preferred formerly, and it is still found in new constructions in some of the East European countries. The other systems require 25 – 40 %

more pipes, the Flat Station system F though the least. Systems B and C are common in new build systems, while the decentralized Flat Station system is still not so common. Until recently it was mostly installed in high quality apartments. The reason is that the installing a substation for every flat in the apartment building normally increases the total investment. However, resent development with increasing energy prices as well as increased focus on environmental impact could give further supports to decentralized systems and individual substations in flats.

Distribution system heat losses

In the following, the pipe heat losses from the alternative distribution systems will be analysed. The following preconditions are used:

- DH design temperatures: 80/40 °C (flow/return)
- Room heating design temperatures: 70/40 °C
- DHW / circ. temperatures risers: 60/55 °C
- DHW(circ) temperatures prepared in flat: 50/(50) °C
- Room temperatures: 20 °C

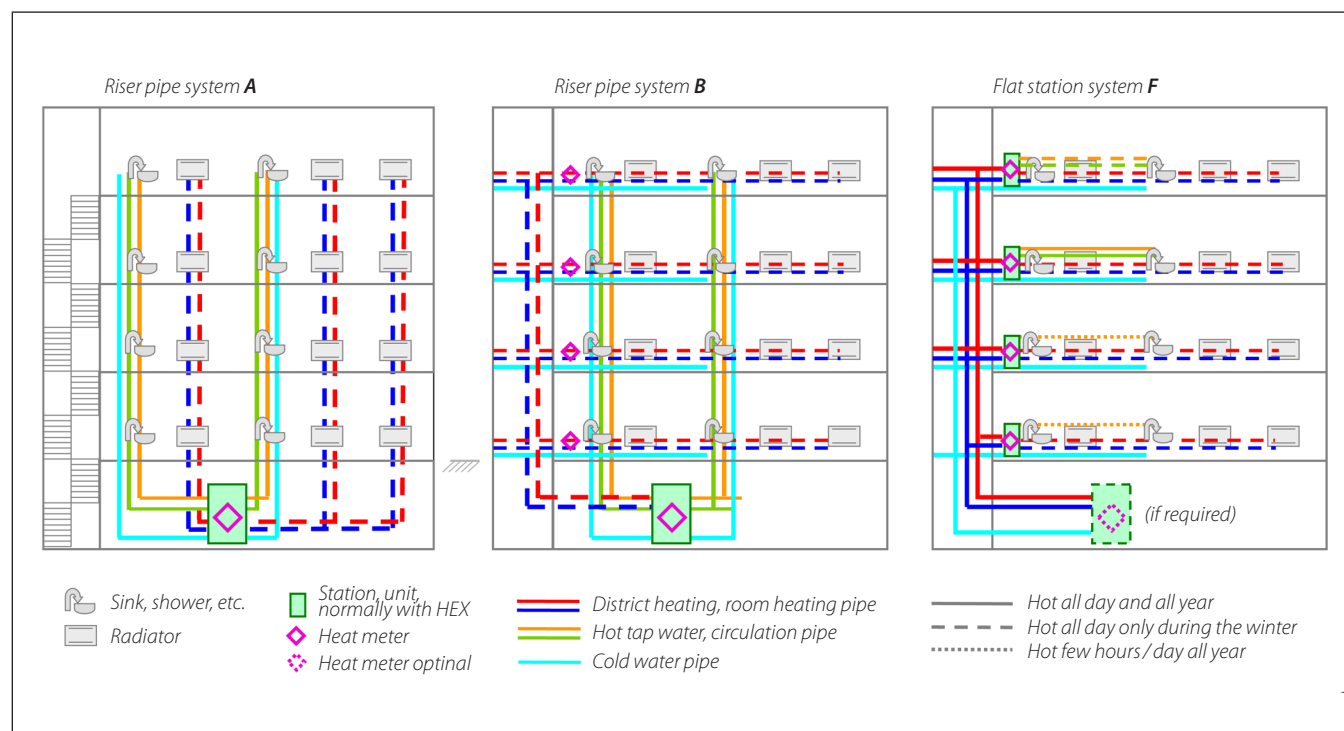


FIGURE 2: Three alternative principal designs of the distribution system in apartment buildings. The fourth alternative, Riser Pipe system C, is almost like system B, but the cold water and DHW pipes rise in the staircase beside the heating pipes

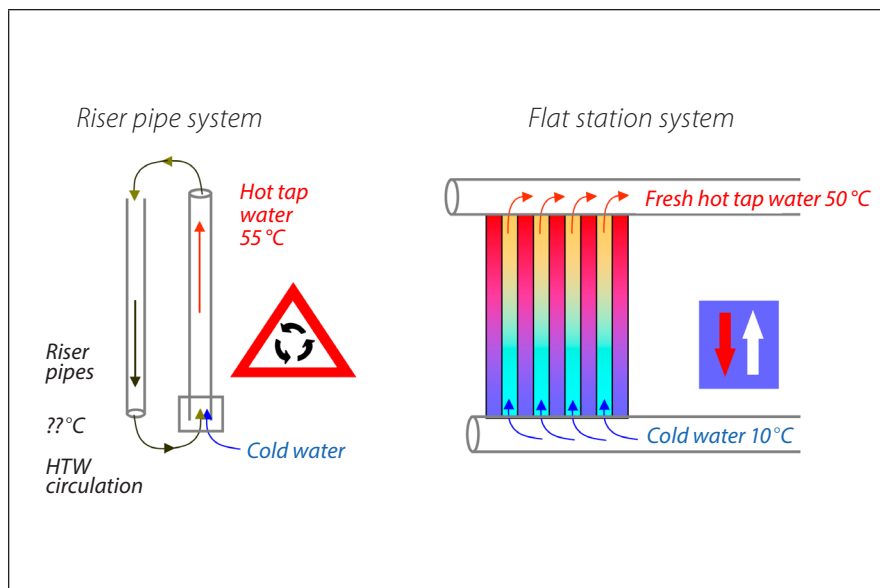


FIGURE 3: Hygiene risk from two basic designs of DHW systems

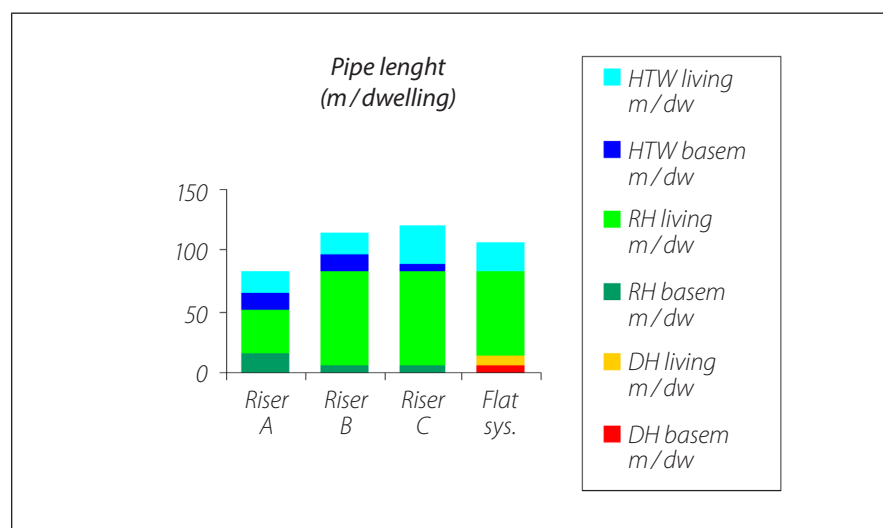


FIGURE 4: Amount of pipes in four basic design alternatives

Danish Technical Insulation Standard requires minimum allowable heat loss constants (W/m), depending on temperatures, annual operation time and pipe diameter. These constants turn out to be quite similar for all the pipes in question. To simplify the preconditions, and make it easier to follow the calculations, a heat loss constant of 0,20 W/m has been chosen for all pipes except of cold water pipes. The pipe losses at design temperatures are included in fig. 5.

The gross heat losses at design temperatures follow the length of the pipes together with pipe design temperatures. However the room heating pipes are often operated with lower temperatures, and they are also kept idle in the summer. In case of the decentralized flat station system, this

also applies to all the DHW pipes. The following operation parameters are used as preconditions:

- DH temperatures spring: 70/30°C (flow/return)
- DH temperatures summer: 60/40°C (flow/return)
- Room heating pipes - ratio of temperature differences of average vs. design: 80%
- Operation time room heating riser pipes: 8 months/year
- Average operation time for room heating "horizontal" pipes inside flat, shut down by individual consumer: 7.6 months/year.
- Operation time DHW pipes in flats: 2 hours per day all year
- Degree of utilisation of loss from pipes in basement for lowest floor flats: 20%

The reason for different operation time of room heating pipes in case of risers and pipes inside the apartments is that the piping of systems B, C, and especially F, makes it possible to make individual adjustments of the room heating season. A resident on the top floor would typically prefer the longest heating season. This will keep room heating risers hot for few weeks extra. Only in case of a decentralized flat station systems, this makes no difference. A good example of that energy savings are related to both individualisation and comfort demand, explained later in the article.

The average losses of the year are included in fig. 6.

In case of the decentralized Flat Station system the heat losses from the DHW pipes are low, as they mostly lay idle. This does not apply to the riser pipe part of systems A, B, and C.

During the heating season, the majority of the heat losses from pipes in living areas are utilised for room heating, though less for riser pipes as mentioned above. The rest of the pipe heat losses, i.e. losses not utilised for room heating, are final losses, also called net losses, (Fig. 7).

It appears that Riser Pipe system C and especially the Flat Station system have the lowest final pipe losses. These losses are mainly from pipes placed in the basement, and the vertical pipes in the staircase during the summer. However, as far as the DH pipes are better insulated than other pipes, the flat station system connected to district heating has the lowest heat losses.

In case of Riser Pipe systems A and B, the DHW and circulation pipes are kept hot all the time, causing considerable pipe heat losses. Only 30% of the DHW and circulation pipe heat losses is utilised for room heating, the rest are final losses.

Figure 8 includes the net (final) losses again, now as annual kilowatt hours.

Typical DHW consumption in a flat is 1 – 2 MWh (1 – 2 persons). This means that the net pipe losses are half of the net DHW consumption in case of systems A and B. According to the literature, domestic hot water riser pipe systems in apartment buildings can even provide bigger losses than the net heat needed for preparing the DHW! This kind of losses is saved in the Flat Station system. The losses from DHW

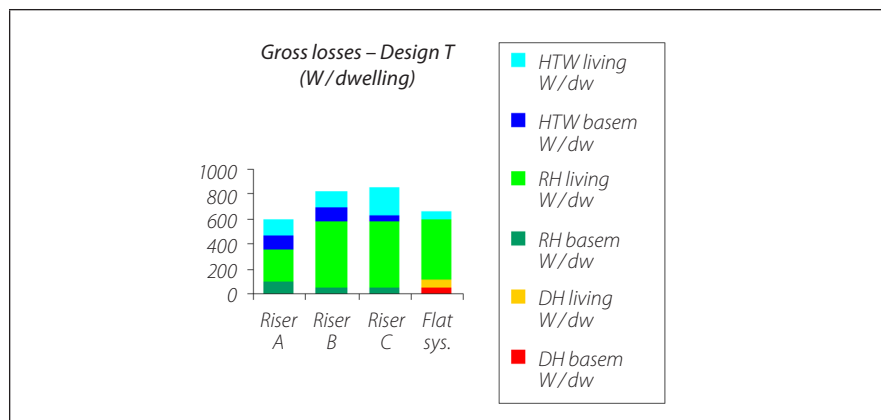


FIGURE 5: Pipe heat flux losses (Watt) at design temperatures

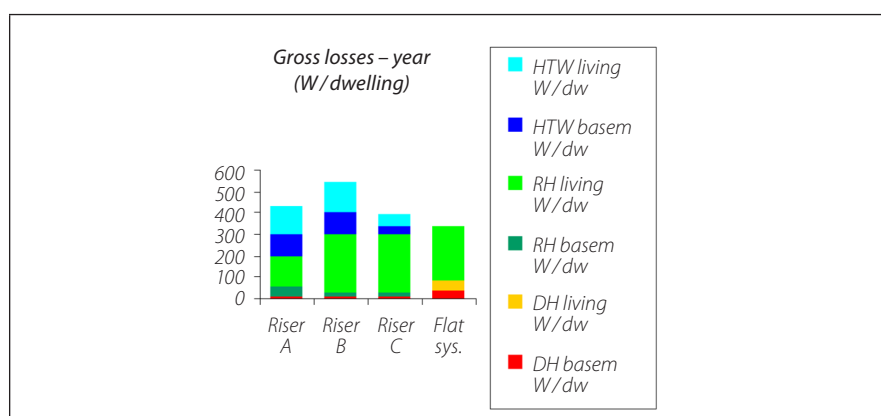


FIGURE 6: Pipe heat flux losses (Watt) as annual averages, after weighing with operation time of each pipe type, as well as variation in pipe temperatures

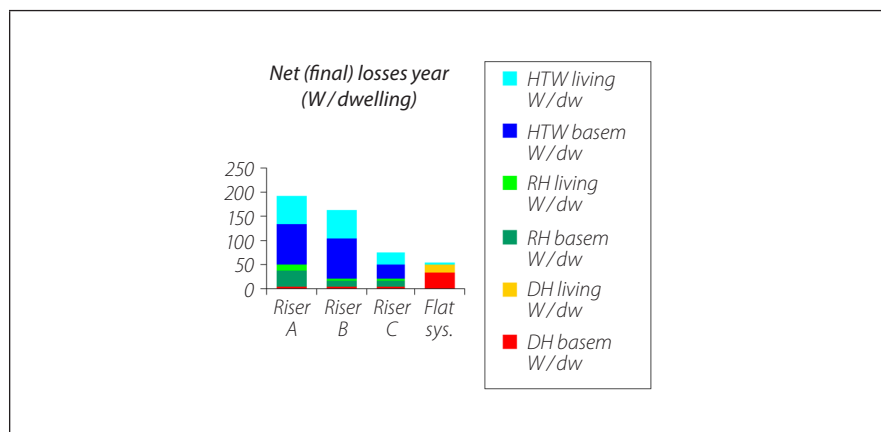


FIGURE 7: Pipe heat flux losses (Watt) as year average, after subtracting heat utilised for room heating.

pipes are replaced by a smaller loss, the losses from the supply pipes in basement and staircase, either district heating pipes or block supply pipes, (both as “DH” in the figure).

Heat losses from the basement substation or boiler have not been included in the comparison between the four systems. This is not necessary as far as the basement substation is similar for all four systems. However, in case of the Flat Station system, no DHW is prepared in the basement, which results in fewer components in the basement substation. In some cases the station is not needed at all. This would save at least 10 W per flat if the alternative was instant hot tap water preparation by heat exchanger, or at least 20 W per flat if the alternative was a hot water tank. On the contrary, heat losses from flat stations would be about 20–40 W, depending on component piping and insulation design.

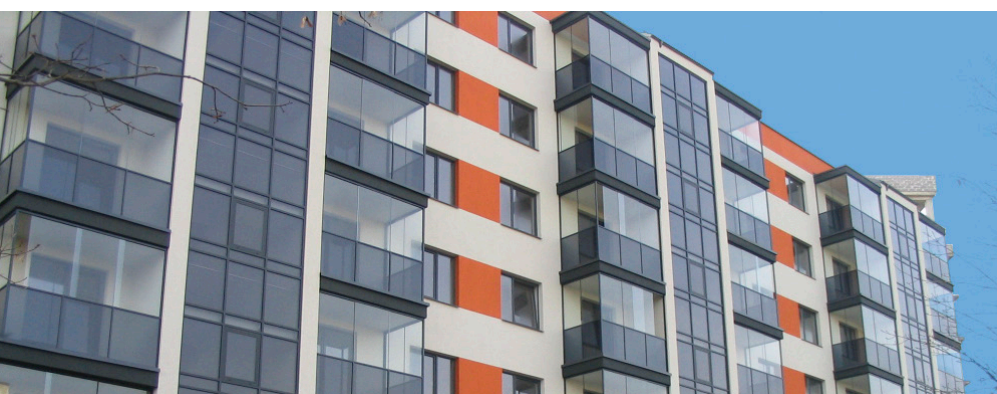
The figures above are for new systems. The heat losses from existing systems are often many times higher.

Comfort and individualisation of controls and metering

In general, the heat supplied from the district heating system to the consumer should match the heat demand of the individual consumer as best as possible. Any difference between the consumer heat demand and the heat supplied makes up an energy saving potential. The energy savings can be obtained by means of control equipment (temperature & hydraulic balancing controls).

Heat Demand and Control of Heat Supply

In theory, it may be possible to design a one pipe riser pipe constant flow heating system with perfect radiator dimensions in an apartment building. In reality, it is not possible to avoid overheating without automatic controls, for the following reasons: the flows can not be balanced; the DH supply temperatures are not precise; the insulation effect of a room differ from preconditions; the wind one day is from the south and the next day from the north; the heat balance is influenced by electrical installations and persons in the room; the residents differ in their preferences about indoor



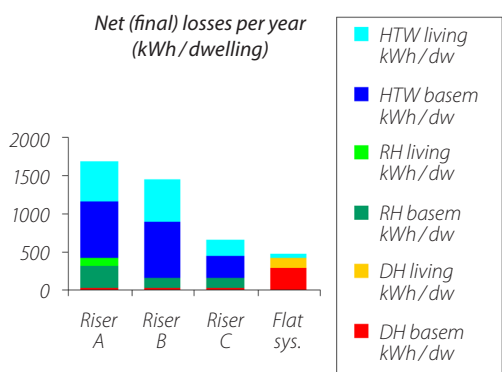


FIGURE 8: Annual, final (net) pipe heat losses (kWh) of four alternative systems

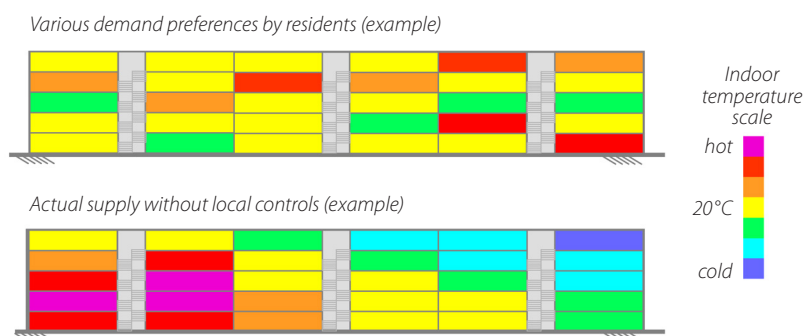


FIGURE 9: Real demand may be different from real supply

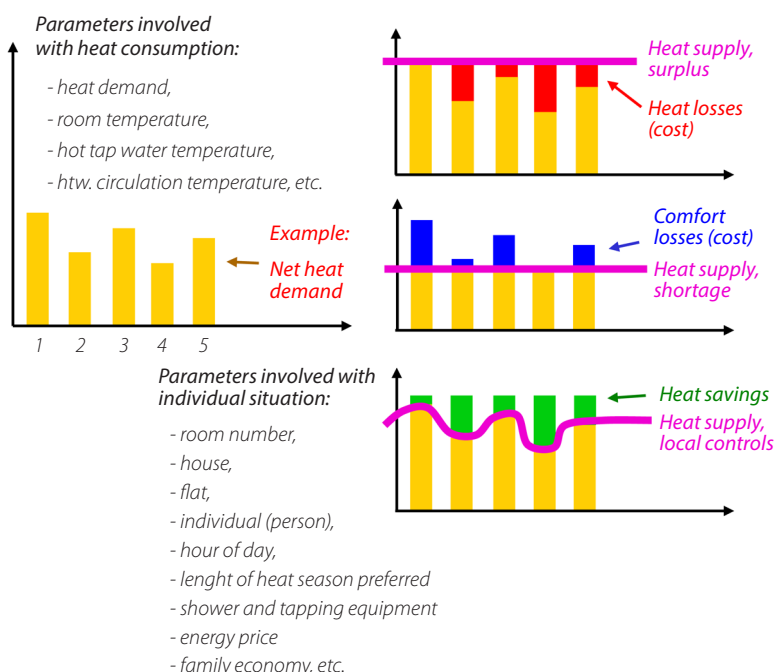


FIGURE 10: The demand – supply difference is an energy saving potential

temperature (Fig. 9), etc. For instance, elderly people and parents to babies may choose higher indoor temperatures, whereas lower temperatures are preferred in bedrooms.

In case of heating systems without automatic controls of sufficient quality, it is necessary to overheat one part of the building to ensure that all residents in another part of the building get sufficient heat. This has resulted in huge energy losses related to high indoor temperatures, the so-called open window losses (Fig. 10).

This design was previously applied in many East European countries in times with low fuel prices. In later periods of recession, the heat supply was limited, leaving some of the residents with very cold rooms. In this case, an even dispersion of the scarce heat would have improved the average comfort level considerably.

In Scandinavia and the colder parts of the Western Europe, thermostatic radiator valves and other types of control valves have become tradition for decades, saving considerable amounts of energy. However, individual metering of each flat in apartment buildings is still quite rare, which means that heat is wasted as illustrated in the following.

Influence of Comfort Demand

Comfort level is an important factor involved with energy consumption. Economic growth results in increased demands of comfort, which in case of non-controlled systems leads to an increasing heat consumption (Fig. 11).

The saving potential of “local” automatic controls would be underestimated, if the “first sight” savings (“year 0”) were not adjusted according to the development (“later”). The correct reference basis is what the heat consumption of the obsolete system would have been in the future. These conditions, together with increasing energy prices, can make investment in a design involving local automatic controls far more feasible than at first sight.

The most common examples of increasing comfort demands are the available higher indoor temperatures, elongated heating seasons, more air ventilation, and a stable suitable hot tap water temperature. The literature includes extensive formulas for, for

instance, how indoor comfort depends on indoor air temperature, draught, radiation, humidity, air dust and chemical composition.

Individualisation of controls and metering save energy

The purpose of automatic control equipment is to fit the heat supply to the individual consumer demands, with a minimum of losses. It is important to distinguish between different levels of individualisation of the controls (see Fig.12).

Typical East European designs are shown in the left side of the figure, while the designs with optimum control performance are found in the right. This design involves thermostatic radiator valves on all radiators and a flat substation with a heat meter for every apartment. This design allows each family to optimise the indoor comfort, DHW preparation and consumption according to the given heat costs, providing maximum energy savings (Fig.13).

Evaluation of the energy saving potential of applying automatic controls only becomes credible when also considering the comfort level. Energy saving data have to be cleaned for differences in the comfort level. If the comfort level were not considered, the most efficient energy savings would be obtained by simply turning off the heat. No controls needed. But as far as the future brings increasing demands for comfort as well as energy savings, a maximum individualisation of controls and metering is the most relevant issue.

Another important effect of an individualised design as the decentralized system with flat stations is that the authorities relatively quickly can obtain optimal energy savings by raising the energy price during energy crises. It should be kept in mind that block distribution systems are normally constructed for the purpose of lasting several decades, while energy crises can occur within unexpectedly. This is especially relevant for most European countries which rely on import of primary energy, like oil, gas etc.

The third important effect of an individualised design as the flat station system is that installations are maintained, as their condition influence the consumer's bill directly. Experience shows that jointly owned

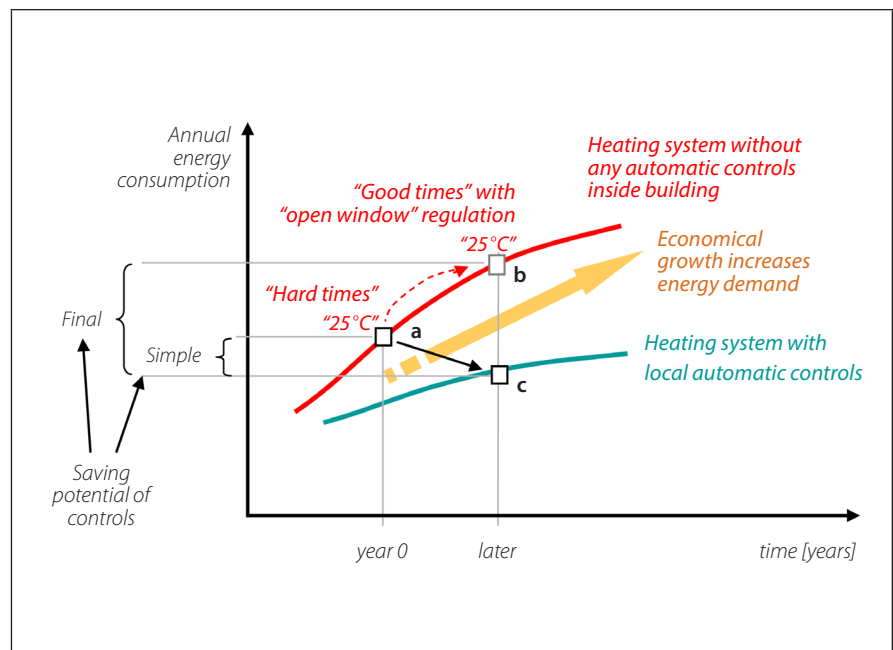


FIGURE 11: Real saving potential might be bigger than the immediate measured saving potential

substations hidden in cellars are poorly maintained, causing unnecessary losses and too high a return temperature in the DH network.

Heat demand and principal design of block distribution system

The flat station system maximises the individualisation of the block distribution system. This distribution design makes it possible to make individual adjustments of for instance the room heating season as well as the hot tap water operation.

According to measurements of a few groups of houses in Denmark between 1991 and 2005, individual billing resulted in savings of 15 – 30 %.

Savings of 15 %, out of an energy cost of EUR 1,000 per year, would generate EUR 1,500 for the consumer over the next ten years, provided that energy prices are fixed.

But both energy prices and comfort demand are likely to increase, which further supports designs with maximum "individualisation" as the decentralized flat station system.

Conclusion

Increasing energy prices together with increasing comfort demand increase the feasibility of distribution designs involving maximum individualisation of heat controls and metering. In case of block distribution system, the decentralized system with flat stations maximises this kind of individualisation with one heat meter for each flat.

The consumer can individually adjust controls for room heating and DHW system. The savings would be 10 – 30 %. The block distribution system losses depend on building geometry, operation temperatures etc. They appear to be highest in case of the old fashioned riser pipe system, and lowest in case of the decentralized flat station system.

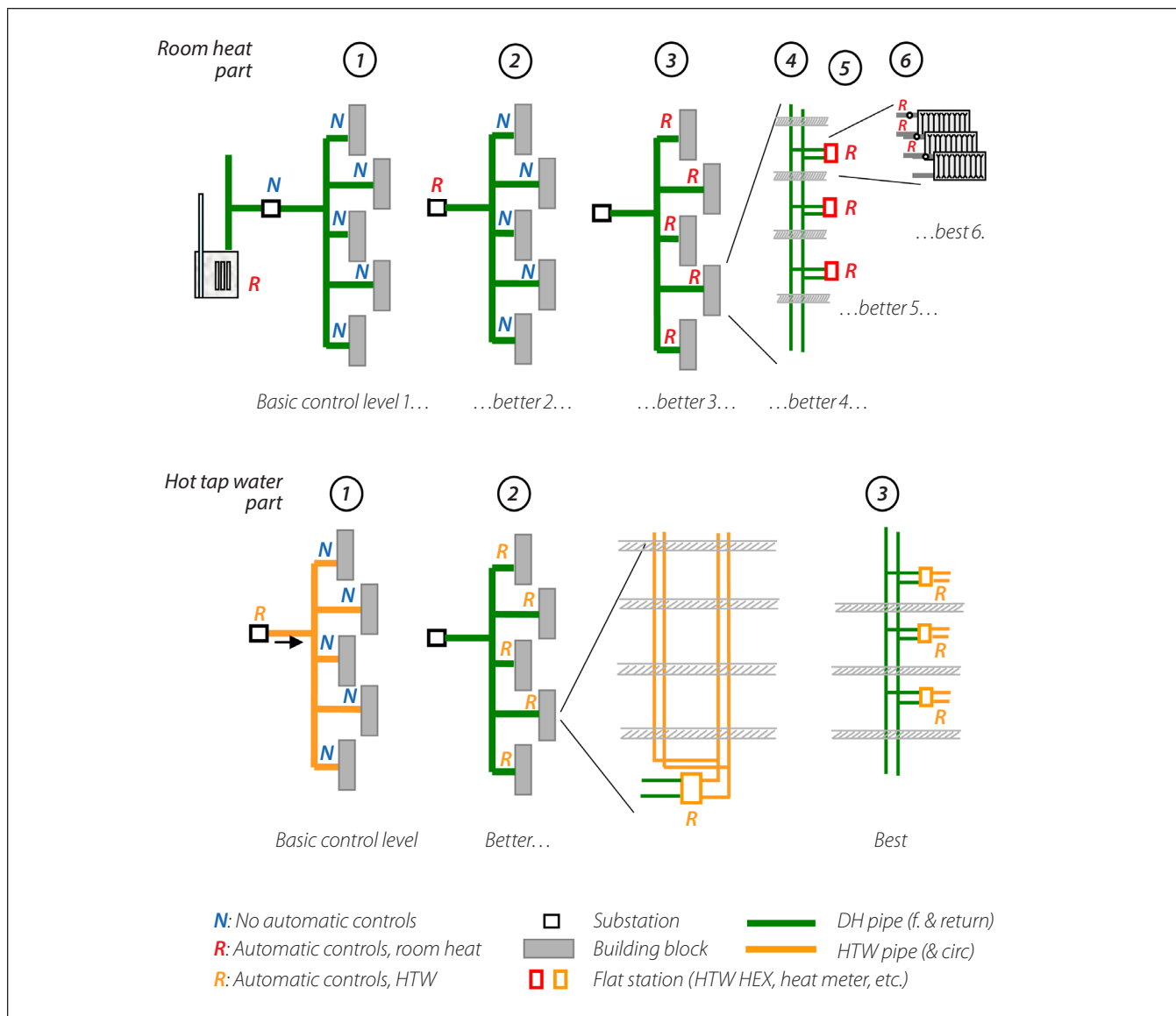


FIGURE 12: Individualisation levels of energy controlling

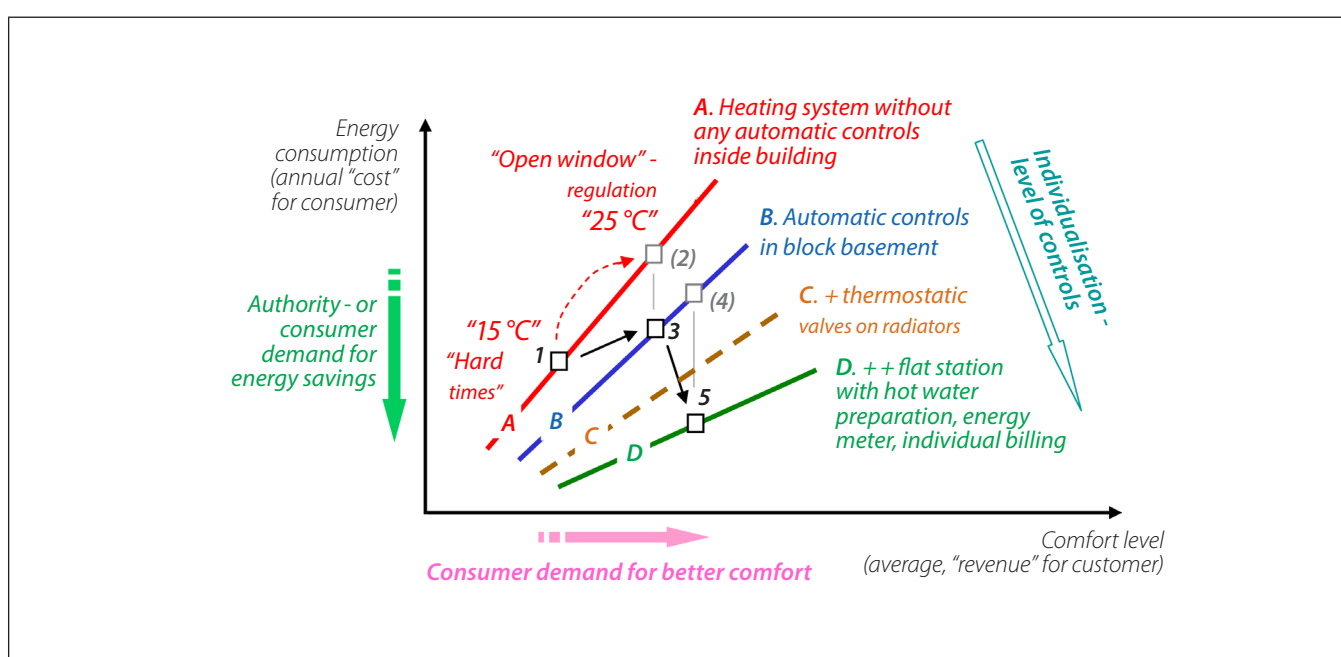


FIGURE 13: Energy savings depend on growth and controls. Higher energy prices and higher comfort level demand require maximum individualisation of controls and metering

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